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EFFECT OF CHITOSAN ON POST-HARVEST SHELF LIFE OF PERSIMMON (*Diospyros kaki* L.)

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ABSTRACT

Persimmon is a climacteric fruit and very perishable. Changes in several physiological attributes greatly affect its quality and market value. The current study was designed to assess the effect of chitosan solution (an edible coating material that can improve postharvest performance) on physico-chemical attributes of persimmon fruit during storage. Persimmon fruits were harvested, cleaned and then dipped in various chitosan concentrations (1%, 2% and 3%) for 5, 10 and 15 min. The treated fruits were stored at 25–29°C, 55–70% RH for 28 days. Results indicated that fruits coated with 3% chitosan solution had maximum volume, firmness, ascorbic acid, titratable acidity and minimum juice, TSS, pH, TSS/acid ratio, decay incidence and weight loss. Similarly, the performance was better in fruits dipped for 15 min. It was concluded that persimmon fruits dipped in 3% chitosan solution for 15 min could improve its postharvest performance when stored under ambient condition.

Key words: chitosan, perishability, persimmon, physico-chemical attributes, shelf life

INTRODUCTION

Persimmon (*Diospyros kaki* L.) fruit belongs to family Ebenaceae and its origin is China [Yokozawa et al. 2007]. Persimmon fruit is considered a neutraceutical, as it is a rich source of dietary fibres, minerals and vitamins that are responsible for reduction of many diseases. Similarly, it also contains carotenoids, ascorbic acid and phenolic contents, having good antioxidant, anticarcinogenic and antimutagenic activities. Persimmon leaves and fruits have been used traditionally in China for the treatment of burns, bleeding, hypertension, paralysis, dyspnoea and cough [Butt et al. 2015].

Persimmon fruits are very perishable in nature and during storage, high rate of water loss due to evaporation and transpiration greatly affects its market value and quality. In addition, the pathogens attack and several physiological disorders also results in short shelf life of the fruits [Gorinstein et al. 2001]. Persimmon fruit ripening is associated with ethylene biosynthesis, pigments changes and increasing concentration

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of total soluble solid. During early maturity, ethylene biosynthesis in persimmon fruit is high and leads to rapid senescence. Therefore, many researchers around the world are using numerous techniques that may help in prolonging the post-harvest life of fruits, especially persimmon, including treatment with hot air [Luo 2006], control and modified atmospheric storages [Dorria et al. 2011], hypobaric treatment [Bibi et al. 2021], gamma irradiations [Golding et al. 2020], hot water and low temperature storages [Rasouli and Khademi 2018] and various types of packaging materials [Cia et al. 2006], etc.

Application of edible coatings i.e. dipping fruits in an edible material that can be eaten with fruit is comparatively a new technique that can be utilized for prolonging its post-harvest life and maintains the quality of fruit. Edible coating material has the ability to form a semi permeable covering on outer surface of the fruit that minimizes loss of water, reduces the rate of respiration, control metabolic and oxidative reactions inside the fruits as well as lower the chances of microbial attack [Vargas et al. 2008]. A large number of edible coating materials including sun flower oil, coconut oil, olive oil, bee wax, carnauba wax, chitosan, etc. have been practiced on different fruits to maximize the postharvest life of fruits and vegetables. Among these edible coating materials, chitosan is a polysaccharide, having high molecular weight that can be obtained by deacetylation of chitin extracted from exoskeletons of insects, crustaceans and fungi [Muzzarelli et al. 2012]. Chitosan not only regulates exchange of respiratory gases but also minimizes transpiration of water from the outer surface of fruits and thus delaying the ripening and senescence processes. Earlier findings have shown that chitosan coating is nontoxic, biodegradable, biocompatible and long lasting having antimicrobial and antifungal properties [Amariz et al. 2010].

Keeping in mind the high perishability characteristics of persimmon fruit and effectiveness of chitosan in preservation of fresh fruits, the present study was planned to study the influence of different chitosan concentrations and dipping time on the physiochemical attributes of persimmon fruits during storage.

MATERIAL AND METHODS

Fruit collection and experimental design. Persimmon fruits were harvested at physiological maturity from an orchard at Horticulture Research Farm, The University of Agriculture Peshawar – Pakistan (UAP). Harvested fruits were safely transported to post-harvest laboratory, Department of Horticulture, UAP. Fruits with uniform maturity and size having no wounds were washed with water and air-dried. The experiment was carried out in Completely Randomize Design (CRD) having two factors factorial arrangement, replicated 3 times. The 2 factors in the experiment were chitosan concentrations (1%, 2% and 3%) and fruit dipping time (5, 10 and 15 min) with a control.

Preparation and application of chitosan coating. For the preparation of various chitosan concentrations (i.e. 1%, 2% and 3%), chitosan (Chitosan powder, Merck, UK) having medium molecular weight and deacetylation degree of 70–85% partly dissolved in water was taken at the rate of 1 g, 2 g and 3 g respectively, and dissolved in 100 mL distilled water separately. Since, chitosan doesn't dissolve easily in water, therefore, for uniform dissolution 0.1 mL of citric acid (Citric acid, Sigma-Aldrich, UK) were added to the solution and placed over magnetic stirrer (MS-H-Pro+, GR Bioteck, UK) at 200 rpm for 1 h. The final pH of the solution was set to 7.0 ±0.2. Furthermore, 480 prewashed persimmon fruits were divided into 4 lots, each lot consisted of 120 fruits and each treatment comprised of 10 fruits. The fruits in each group were dipped in 0 (distilled water), 1%, 2% and 3% chitosan solution for 0 (no dipping), 5, 10 and 15 min, respectively. The treated fruits were then allowed to air dry for about 30 min and then stored at 24 ±2°C with 55–70% relative humidity for 28 days.

Studied attributes. Following attributes were studied during the experiment, data for each parameter was obtained at each seven days interval for the whole period of the experiment and averages were calculated.

Fruit volume (cm^3) and juice content (%). Persimmon fruits were randomly taken from each lot and its volume was measured using liquid displacement method, following the procedure explained by Celik and Ercisli [2008]. Similarly, for the determination of fruit juice

content, persimmon fruits were weighed using electronic compact scale (SF-400C, Guangdong, China, Mainland). Then, the juice was extracted from each fruit with the help of electric blender and poured through the cloth, further, weight of the juice was measured. Per cent fruit juice content was determined using formula in eq. 1.

$$\text{Juice content (\%)} = \frac{\text{Total weight of the juice (g)}}{\text{Weight of the fruit (g)}} \times 100 \quad (1)$$

Fruit firmness (kg cm^{-2}). Firmness of the persimmon fruits was analysed using penetrometer (FT-327, Wagner FT Fruit Tester, Greenwich, USA). For firmness measurements, 0.3–0.5 mm shell was removed and then measurements were recorded. Two measurements were made per fruit at right angles to each other on pared areas on the equator of the fruit.

Total soluble solid (°Brix). The total soluble solid content (TSS, °Brix) was determined by obtaining 2 drops of juice from the 2 cut ends of each fruit and then placed on digital refractometer (RHB-32ATC, Shandong, China, Mainland)).

Titratable acidity (%). For determining the titratable acidity, standard procedure was followed, briefly, in a 100 mL volumetric flask, 10 mL fruit juice were taken and diluted up to the mark. In a titration flask 10 mL of the diluted samples were taken and as an indicator 2–3 drops of phenolphthalein (Phenolphthalein, Sigma-Aldrich, UK) were added and then titrated against 0.1 N NaOH (Sodium hydroxide solution, Sigma-Aldrich, UK) until the light pink colour appeared. Consecutive 3 readings were taken and per cent titratable acidity was calculated following the formula in eq. 2.

$$\text{Titratable acidity (\%)} = \frac{N \times T \times F \times 100}{D \times S} \times 100 \quad (2)$$

where:

N – NaOH normality,
T – volume of NaOH (mL),
F – constant acid factor 0.0064 (citric acid),
D – fruit juice volume (mL),
S – volume (mL) of diluted sample taken for titration.

TSS/acid ratio. The TSS/acid ratio was obtained from total soluble solid and titratable acidity using eq. 3.

$$\text{TSS/acid} = \frac{\text{Total soluble solid}}{\text{Titratable acidity}} \quad (3)$$

Fruit juice pH. The fruit juice pH was calculated with the help of pH meter (inoLab® pH 7110 Benchtop Meters, Swedesboro, USA). The meter was standardized in buffer solution before analysis and placed in extracted juice to determine the pH.

Ascorbic acid content (mg 100 g^{-1}). The ascorbic acid content from persimmon fruit was determined by taking 10 mL of the extracted fruit juice in a graduated cylinder. Then, oxalic acid solution was added to the fruit juice to raise the volume up to 100 mL, so as to make 10% solution. Further, this solution was titrated from the burette containing dye (50 mg of 2,6-dichlorophenolindophenol + 42 mg baking soda) until the pink colour appeared. The same procedure was repeated 3 times for each sample and readings were noted and averaged for final analysis. Ascorbic acid content in persimmon fruit was calculated using the formula in eq. 4.

$$\text{Ascorbic acid content } \left(\frac{\text{mg}}{100}\text{g}\right) = \frac{F \times T \times 100}{D \times S} \times 100 \quad (4)$$

where:

F – dye factor,
T – dye used for sample titration (mL),
D – sample taken for dilution (mL),
S – diluted juice taken for titration (mL).

Fruit decay incidence (%). Data for fruit decay incidence was procured by visual observing each fruit in the lot for any decay or disease symptoms. The decayed fruits were counted and tossed out of the lot. Finally, per cent disease incidence was calculated at the end of the experiment with the help of formula given in eq. 5.

$$\text{Decay incidence (\%)} = \frac{\text{Number of decayed fruits}}{\text{Total number of fruits}} \times 100 \quad (5)$$

Weight loss (%). At the start of the experiment all fruits in each lot were weighed with the help of electronic compact scale (SF-400C, Guangdong, China (Mainland)). Fruits were then stored for 28 days for the experiment and weighed again at the end of the experiment. Weight loss was expressed as a per cent of its original weight and was calculated with the help of eq. 6.

$$\text{Weight loss (\%)} = \frac{X-Y}{X} \times 100 \quad (6)$$

where:

X – weight of fresh fruit (g),

Y – weight of fruit after storage (g).

Statistical procedure. Data for all the studied attributes were recorded through standard procedure suitable for completely randomized design (CRD) having 2 factors. Since, all attributes were studied at each 7 days interval until the end of experiment, therefore, data for each parameter was averaged and then subjected to analysis of variance. For the analysis of recorded data, STATISTIX (v. 8.1) was used and when statistical differences were found then least significant difference at 5% level of probability was used for further analyses.

RESULTS

Persimmon fruit volume (cm³), juice content (%), firmness (kg cm⁻²) and total soluble solid (°Brix). The obtained data on persimmon fruit volume, fruit juice content, fruit firmness and total soluble solid (TSS) was significantly affected by different chitosan concentrations and its dipping time (Tab. 1). From the data it can be seen that maximum fruit volume (99.71 cm^3), fruit firmness (2.25 kg cm^{-2}), minimum fruit juice content (28.39%) and TSS (16.15°Brix) were noticed in the fruits dipped in 3% chitosan solution. While, minimum fruit volume (79.87 cm^3), fruit firmness (0.83 kg cm^{-2}), maximum juice content (41.27%) and TSS (23.82°Brix) were noted in the fruits that were dipped only in distilled water (with no chitosan solution) (Fig. 1a). Similarly, the obtained data on chitosan dipping time showed that, maximum fruit volume (95.23 cm^3), fruit firmness (2.11 kg cm^{-2}), minimum fruit juice content (29.72%) and TSS (18.08°Brix) were noticed in fruits dipped in chitosan solution for 15 min. While minimum fruit volume (87.48 cm^3), fruit firmness (1.05 kg cm^{-2}), maximum fruit juice content (38.90%) and TSS (21.44°Brix) were noted in persimmon fruits that were not dipped in chitosan (control) (Fig. 1b). Results also indicated that interaction between chitosan concentrations and its dipping time significantly affected the fruit juice content, firmness and TSS of persimmon fruits (Tab. 1). Data showed that fruit juice content and TSS significantly decreased with an increase in the chitosan concentrations and its dipping time (Figs 4a and 4c), whereas, fruit firmness significantly increased with an increase in the chitosan concentrations and its dipping time (Fig. 4b). Further, the fruit volume, juice content and fruit firmness decreased with an increase in the storage duration at all chitosan concentrations and dipping time. In contrast the TSS increased with an increase in the storage duration (Tabs 2–5).

Titratable acidity (%), TSS/acid ratio, fruit juice pH and ascorbic acid content of persimmon. Titratable acidity (%), TSS/acid ratio, fruit juice pH and ascorbic acid of persimmon fruits were significantly affected by various levels of chitosan concentration and dipping time (Tab. 1). The interaction was also found significant except for fruit juice pH. Higher value for titratable acidity (0.28%), ascorbic acid content (28.10 mg $100g^{-1}$), minimum TSS/acid ratio (58.83) and fruit juice pH (5.46) was observed in fruits that were dipped in 3% chitosan solution (Fig. 2a). Similarly, minimum titratable acidity (0.18%), ascorbic acid content (16.39 mg $100g^{-1}$), maximum TSS/acid ratio (79.27) and fruit juice pH (5.62) was noted in fruits dipped in distilled water (0% chitosan solution) (Fig. 2a). Regarding the means for chitosan dipping duration, persimmon fruits dipped in chitosan solution for 15 min showed maximum titratable acidity (0.26 %), ascorbic acid content (25.04 mg $100g^{-1}$), minimum TSS/acid ratio (63.31) and fruit juice pH (5.47) (Fig. 2b). Similarly, persimmon fruits dipped in distilled water without any chitosan solution showed minimum titratable acidity (0.21%), ascorbic acid content (18.66 mg $100g^{-1}$), maximum TSS/acid ratio (72.68) and fruit juice pH (5.61) (Fig. 2b). The interaction between chitosan concentration and its dipping time showed that increasing the concentration of chitosan significantly increased the titratable acidity and ascor-

Table 1. Analysis of variance of the studied attributes of persimmon

SOV	DF	Mean square									
		FV	FJC	FF	TSS	TA	TSS/acid ratio	FJP	AA	FD	WL
CC	3	900.09*	449.91*	6.11*	143.11*	0.02*	1000.65*	0.06*	366.37*	1787.39*	931.63*
DT	3	147.97*	247.08*	3.91*	28.66*	0.008*	232.26*	0.04*	112.28*	713.30*	185.63*
CC × DT	9	63.93^{ns}	87.100*	1.22*	7.72*	0.003*	131.51*	0.01^{ns}	51.65*	171.47*	70.29*
Error	32	35.04	2.68	0.007	2.83	0.0002	3.72	0.006	2.11	3.34	2.01

CC – chitosan concentrations, DT – dipping time, SOV – source of variation, DF – degree of freedom, FV – fruit volume, FJC – fruit juice content, FF – fruit firmness, TSS – total soluble solid, TA – titratable acidity, FJP – fruit juice pH, AA – ascorbic acid, FD – fruit decay, WL – weight loss
* – significant at 5% level of significance
ns – non significant at 5% level of significance

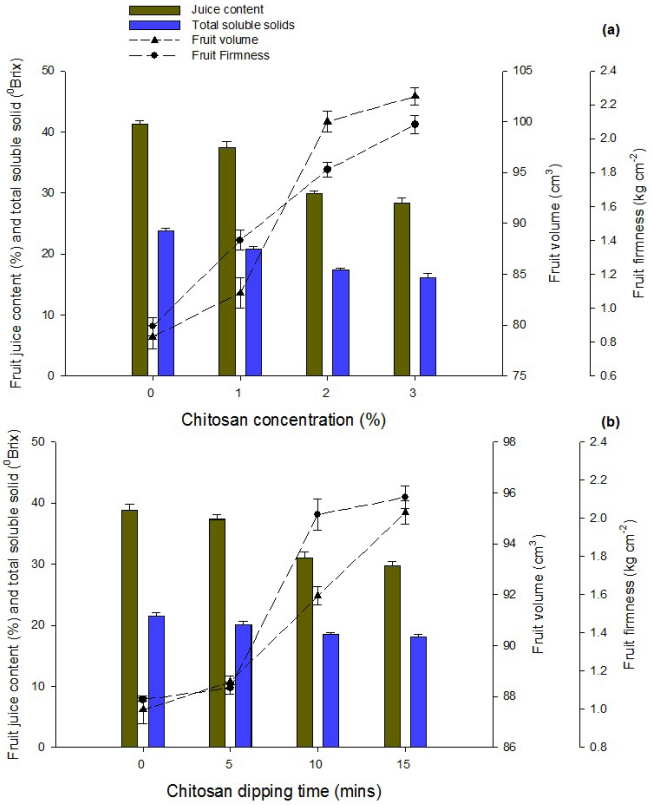

Fig. 1. Fruit juice content (%), total soluble solid (°Brix), fruit volume (cm^3) and fruit firmness (kg cm^{-2}) of persimmon as affected by: **a)** chitosan concentrations (%) and **b)** chitosan dipping time (min). Each graph is an average of 15 fruits. Error bars represents standard error for each attribute

bic acid content of the fruit, while, decreasing the TSS/acid ratio (Figs 4b, 4e and 4f). Likewise, it was noted that titratable acidity and ascorbic acid content decreased with an increase in the storage duration for all chitosan concentrations and dipping time but TSS/acid ratio increased with an increase in the storage duration (Tabs 6, 7 and 9).

Fruit decay (%) and weight loss (%). Data from the experiment indicated that fruit decay incidence and weight loss were significantly affected by various chitosan concentrations and dipping time (Tab. 1). The interactive effect of chitosan concentration and its dipping time was also found significant for fruit decay and weight loss (Tab. 1). The highest values of decay incidence and weight loss (48.58 and 29.79%, respectively) were recorded for fruits dipped in distilled water (no chitosan solution), while fruit decay (21.73%) and weight loss (10.80%) was significantly controlled when persimmon fruits were dipped in 3% chitosan concentration (Fig. 3a). Concerning the dipping time, it can be seen that while increasing the duration of dipping from 0 to 15 min significant decrease in fruit decay from 41.14% to 25.04% and weight loss from 23.51% to 14.96% (Fig. 3b). Similarly, interactive effect of chitosan concentration and dipping time indicated that increased concentration of chitosan and dipping duration controlled the fruit decay and weight loss effectively (Fig. 5a and 5b). Furthermore, the data revealed that both weight loss and fruit decay increased with an increase in the storage duration for all chitosan concentrations and dipping time (Tabs 10 and 11).

DISCUSSION

It is evident from the mean data that increasing the concentration of chitosan and its dipping time reduces fruit juice content. This might be due to the fact that application of chitosan edible coatings suppresses the

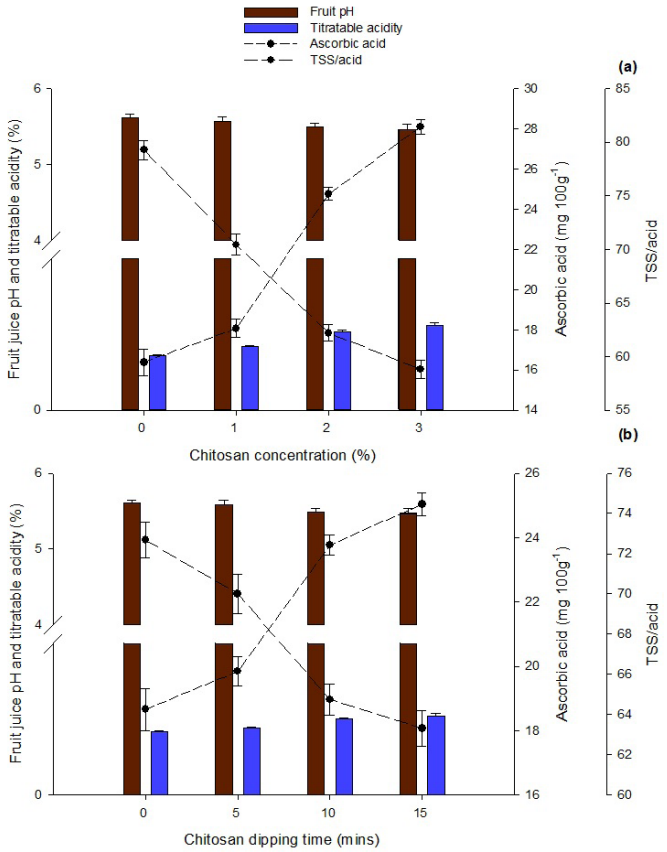

Fig. 2. Effect of: **a)** chitosan concentrations (%) and **b)** chitosan dipping time (min) on persimmon fruit juice pH, titratable acidity (%), ascorbic acid (mg 100 g^{-1}) and TSS/acid ratio. Each graph is an average of 15 fruits. Error bars represents standard error for each attribute

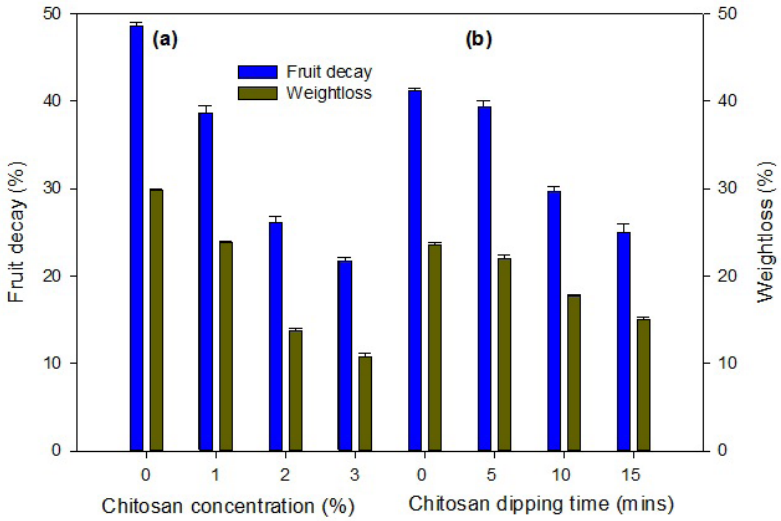

Fig. 3. Fruit decay (%) and weight loss (%) of persimmon as affected by: **a)** chitosan dipping time (min) and **b)** chitosan concentration (%). Each graph is an average of 15 fruits. Error bars represents standard error for each attribute

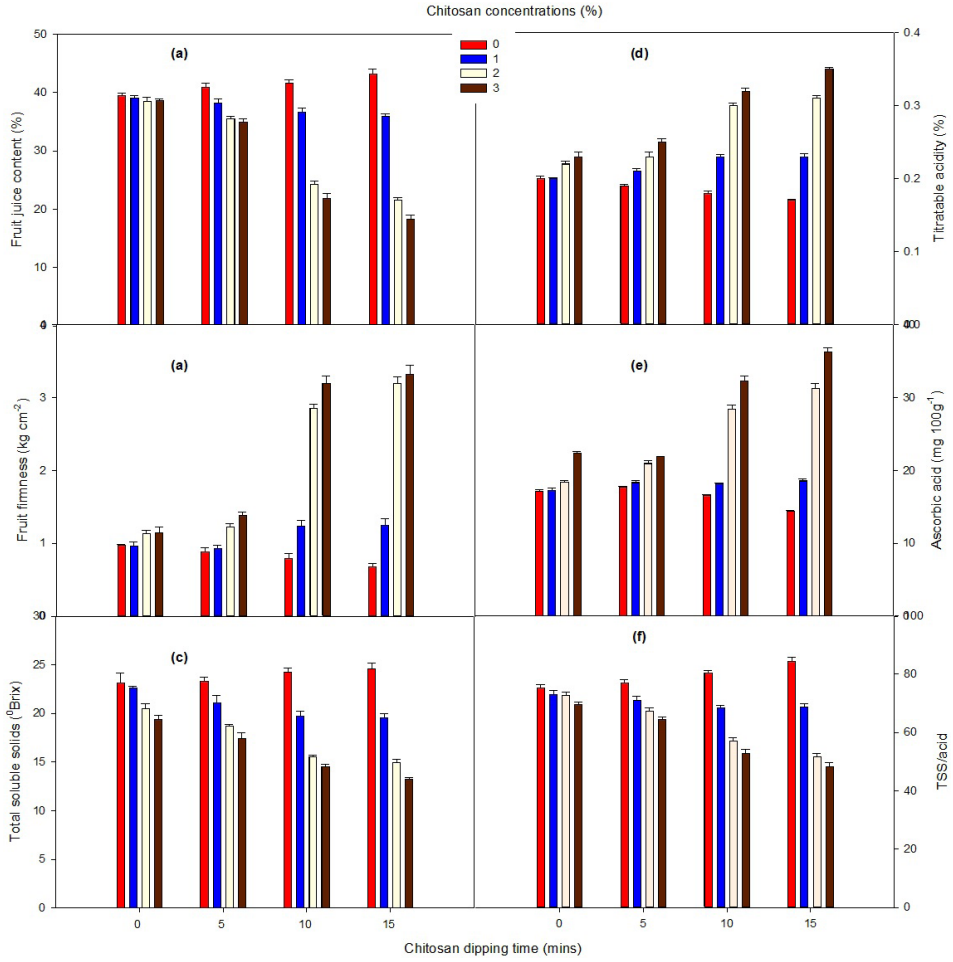

Fig. 4. Interactive effects of chitosan concentrations (%) and dipping time (min) on: **a)** fruit juice content (%), **b)** titratable acidity (%), **c)** fruit firmness (kg m^{-2}), **d)** ascorbic acid (mg $100g^{-1}$), **e)** total soluble solid (°Brix), **f)** TSS/acid ratio of persimmon. Each graph is an average of 5 fruits. Error bars represents standard error for each attribute.

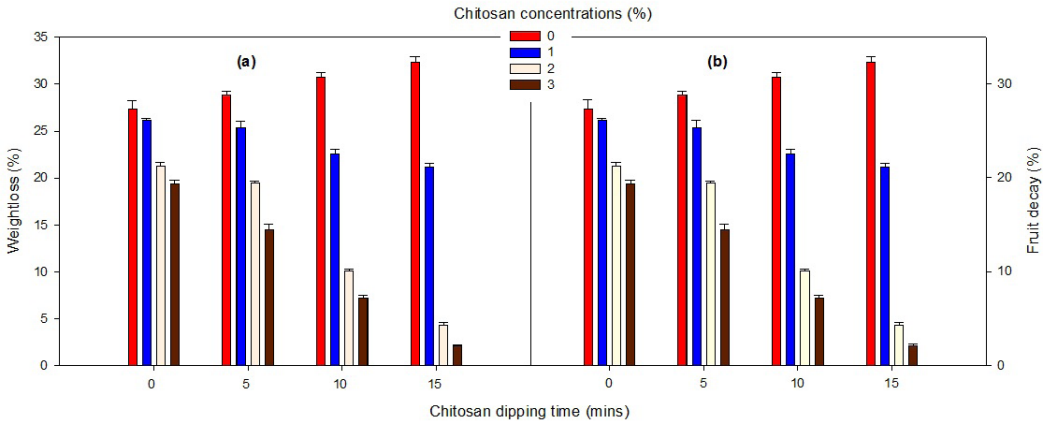

Fig. 5. a) Weight loss (%) and **b)** fruit decay (%) of persimmon as affected by the interactive effect of chitosan concentration (%) and its dipping time (min). Each graph is an average of 5 fruits. Error bars represents standard error for each attribute

Table 2. Interaction of chitosan concentrations and dipping time on fruit volume (cm^3) of persimmon during storage

Chitosan concentration (%)	Chitosan dipping time (min)	Storage durations (days)				
		fresh	7	14	21	28
0	0	122.27	102.23	93.40	86.20	82.81
0	5	123.43	111.40	108.03	85.88	81.18
0	10	124.33	111.43	103.47	85.80	79.16
0	15	124.77	110.57	93.90	86.17	76.33
1	0	124.93	102.03	102.83	86.30	85.56
1	5	123.47	107.65	105.67	89.17	86.11
1	10	121.97	115.90	96.48	81.63	89.13
1	15	119.87	104.92	101.00	92.63	80.82
2	0	123.50	98.90	91.76	89.12	56.82
2	5	122.37	92.33	91.65	83.94	76.93
2	10	123.77	110.20	95.88	94.03	88.98
2	15	124.60	121.01	104.10	104.53	101.17
3	0	124.50	119.05	101.79	92.43	75.80
3	5	127.83	99.92	95.31	92.92	80.30
3	10	126.13	114.37	113.70	103.67	102.47
3	15	121.63	111.57	107.43	93.87	85.77

Table 3. Interaction of chitosan concentrations and dipping time on fruit juice content (%) of persimmon during storage

Chitosan concentration (%)	Chitosan dipping time (min)	Storage durations (days)				
		fresh	7	14	21	28
0	0	94.53	91.57	75.50	74.82	39.52
0	5	94.05	86.51	74.17	69.50	40.87
0	10	92.90	91.00	75.03	70.07	41.59
0	15	93.08	91.40	74.42	70.63	43.11
1	0	93.18	89.96	74.41	70.66	39.11
1	5	92.25	80.03	78.99	69.58	38.15
1	10	92.16	86.02	81.81	81.38	36.61
1	15	93.72	91.49	86.03	82.32	35.95
2	0	93.78	90.33	73.40	73.32	38.45
2	5	93.33	89.30	88.80	84.09	35.49
2	10	93.08	88.95	88.28	85.94	24.28
2	15	94.72	88.83	86.04	82.72	21.52
3	0	93.70	88.22	73.50	69.92	38.55
3	5	94.71	84.58	84.10	81.43	34.87
3	10	93.99	85.22	81.67	71.86	21.85
3	15	93.91	84.21	79.86	68.01	18.32

Table 4. Interaction of chitosan concentrations and dipping time on fruit firmness (kg cm^{-2}) of persimmon during storage

Chitosan concentration (%)	Chitosan dipping time (min)	Storage durations (days)				
		fresh	7	14	21	28
0	0	3.40	2.69	2.09	1.02	0.97
0	5	3.50	2.79	2.14	1.06	0.88
0	10	3.47	2.76	2.25	1.04	0.79
0	15	3.57	2.68	2.07	1.10	0.68
1	0	3.44	2.75	2.12	1.04	0.96
1	5	3.64	2.82	2.09	1.08	0.93
1	10	3.67	2.70	2.05	1.07	1.24
1	15	3.45	2.77	2.05	1.08	1.25
2	0	3.42	2.74	2.09	1.02	1.13
2	5	3.51	2.77	2.10	1.05	1.23
2	10	3.45	2.90	2.36	1.19	1.19
2	15	3.49	3.19	2.69	2.32	1.04
3	0	3.37	2.73	2.07	1.15	1.03
3	5	3.40	2.81	2.05	1.38	1.04
3	10	3.53	3.19	2.74	2.08	1.06
3	15	3.44	3.32	2.73	2.06	1.05

Table 5. Interaction of chitosan concentrations and dipping time on total soluble solids (°Brix) of persimmon during storage

Chitosan concentration (%)	Chitosan dipping time (mins)	Storage durations (days)				
		fresh	7	14	21	28
0	0	17.27	17.67	19.53	22.00	23.15
0	5	16.63	18.30	20.03	22.00	23.35
0	10	17.30	18.53	19.90	17.30	24.24
0	15	16.87	17.23	19.90	22.33	24.57
1	0	17.42	17.47	19.47	22.67	23.33
1	5	18.83	19.97	20.61	21.11	23.00
1	10	14.88	19.73	19.90	20.87	23.00
1	15	14.42	19.52	20.20	21.67	24.02
2	0	16.50	17.90	20.00	20.53	22.33
2	5	16.92	18.67	20.04	21.78	22.00
2	10	15.55	15.73	19.05	21.63	22.33
2	15	14.97	15.33	16.13	21.08	22.67
3	0	19.40	16.67	18.33	19.43	22.00
3	5	15.67	17.41	22.33	22.90	23.27
3	10	14.51	18.97	21.33	21.60	24.10
3	15	13.27	18.80	20.70	22.00	22.83

Table 6. Interaction of chitosan concentrations and dipping time on titratable acidity (%) of persimmon during storage

Chitosan concentration (%)	Chitosan dipping time (mins)	Storage durations (days)				
		fresh	7	14	21	28
0	0	0.73	0.47	0.37	0.33	0.20
0	5	0.77	0.43	0.40	0.30	0.19
0	10	0.60	0.37	0.37	0.32	0.18
0	15	0.70	0.43	0.30	0.32	0.17
1	0	0.73	0.37	0.37	0.27	0.20
1	5	0.83	0.40	0.39	0.33	0.21
1	10	0.43	0.39	0.37	0.23	0.23
1	15	0.60	0.43	0.50	0.23	0.23
2	0	0.60	0.40	0.40	0.37	0.22
2	5	0.56	0.43	0.37	0.30	0.23
2	10	0.49	0.47	0.37	0.30	0.30
2	15	0.50	0.40	0.40	0.31	0.27
3	0	0.60	0.40	0.40	0.34	0.23
3	5	0.53	0.40	0.40	0.30	0.25
3	10	0.50	0.42	0.37	0.32	0.27
3	15	0.47	0.38	0.35	0.33	0.27

Table 7. Interaction of chitosan concentrations and dipping time on TSS/acid ratio of persimmon during storage

Chitosan concentration (%)	Chitosan dipping time (mins)	Storage durations (days)				
		fresh	7	14	21	28
0	0	23.88	42.32	54.37	63.35	75.27
0	5	20.81	50.08	54.10	67.82	77.07
0	10	30.89	53.33	55.04	55.33	80.37
0	15	26.41	48.65	52.87	54.47	84.37
1	0	24.13	54.10	54.17	66.90	73.17
1	5	25.79	54.37	49.93	61.00	71.17
1	10	55.13	54.67	55.36	65.72	68.55
1	15	33.10	48.03	54.37	68.47	68.86
2	0	15.53	45.68	54.37	52.21	72.68
2	5	37.33	50.78	53.97	67.33	85.83
2	10	37.99	41.27	43.87	53.17	57.13
2	15	40.69	42.17	47.23	51.66	54.63
3	0	32.81	48.50	52.72	54.17	69.60
3	5	43.91	54.60	64.45	65.73	75.52
3	10	48.20	52.01	52.93	55.17	84.30
3	15	48.37	49.66	49.43	54.90	80.47

Table 8. Interaction of chitosan concentrations and dipping time on fruit juice pH of persimmon during storage

Chitosan concentration (%)	Chitosan dipping time (mins)	Storage durations (days)				
		fresh	7	14	21	28
0	0	5.37	5.60	5.68	6.03	6.13
0	5	5.28	5.62	5.65	5.94	6.00
0	10	5.12	5.63	5.65	5.77	6.14
0	15	5.36	5.65	5.67	5.83	6.03
1	0	5.27	5.62	5.69	5.83	6.19
1	5	5.41	5.62	5.67	5.69	5.70
1	10	5.42	5.53	5.59	5.66	5.90
1	15	4.99	5.51	5.53	5.66	6.15
2	0	5.12	5.59	5.69	6.06	6.17
2	5	5.41	5.52	5.58	5.67	5.98
2	10	5.41	5.46	5.59	5.66	5.85
2	15	5.28	5.40	5.47	5.61	5.86
3	0	5.08	5.57	5.69	5.83	6.07
3	5	5.40	5.41	5.55	5.67	5.88
3	10	5.28	5.31	5.39	5.66	5.77
3	15	5.30	5.35	5.49	5.66	5.70

Table 9. Interaction of chitosan concentrations and dipping time on ascorbic acid content of persimmon during storage

Chitosan concentration (%)	Chitosan dipping time (mins)	Storage durations (days)				
		fresh	7	14	21	28
0	0	61.60	60.60	35.46	21.15	17.13
0	5	63.00	61.00	32.99	18.56	16.94
0	10	61.42	59.42	25.47	16.63	13.63
0	15	60.27	58.27	19.71	14.45	8.30
1	0	40.08	37.08	34.77	23.59	17.25
1	5	62.50	58.50	36.82	26.63	18.34
1	10	63.60	61.40	42.67	29.40	18.13
1	15	62.55	61.55	35.36	25.60	18.57
2	0	61.52	57.52	35.61	24.22	18.43
2	5	63.71	58.71	40.85	30.35	20.95
2	10	65.44	59.44	46.71	37.38	28.38
2	15	61.63	60.63	42.37	39.48	31.27
3	0	61.04	57.04	36.09	25.46	21.87
3	5	65.48	62.48	42.42	37.49	22.34
3	10	65.69	63.69	49.04	40.35	32.31
3	15	73.34	70.34	40.38	36.22	32.41

Table 10. Interaction of chitosan concentrations and dipping time on weight loss (%) of persimmon during storage

Chitosan concentration (%)	Chitosan dipping time (min)	Storage durations (days)				
		fresh	7	14	21	28
0	0	0.00	6.42	19.11	23.04	27.31
0	5	0.00	6.28	20.13	21.70	28.81
0	10	0.00	6.13	20.03	21.43	30.76
0	15	0.00	6.08	19.71	21.60	32.31
1	0	0.00	6.68	19.27	21.87	26.17
1	5	0.00	5.12	13.43	17.54	25.33
1	10	0.00	3.99	12.00	15.07	22.52
1	15	0.00	4.17	13.47	14.98	21.12
2	0	0.00	6.26	17.03	18.50	21.23
2	5	0.00	5.12	10.99	16.87	19.43
2	10	0.00	4.32	10.11	10.77	14.56
2	15	0.00	3.90	4.31	12.20	14.00
3	0	0.00	5.74	18.97	19.34	19.70
3	5	0.00	3.68	10.30	13.49	14.51
3	10	0.00	4.61	7.23	10.70	17.00
3	15	0.00	2.12	4.31	11.98	16.00

Table 11. Interaction of chitosan concentrations and dipping time on fruit decay (%) of persimmon during storage

Chitosan concentration (%)	Chitosan dipping time (min)	Storage durations (days)				
		fresh	7	14	21	28
0	0	0.00	18.59	42.99	46.37	60.64
0	5	0.00	23.87	46.86	46.94	67.44
0	10	0.00	28.99	49.53	51.97	75.38
0	15	0.00	38.18	61.90	51.53	84.67
1	0	0.00	13.59	32.30	45.13	53.01
1	5	0.00	0.00	28.85	40.42	43.21
1	10	0.00	9.75	30.73	35.22	44.36
1	15	0.00	14.23	31.14	35.26	52.74
2	0	0.00	0.00	0.00	8.25	35.51
2	5	0.00	12.67	32.31	37.28	50.96
2	10	0.00	0.00	10.47	21.37	21.70
2	15	0.00	10.32	11.19	23.36	28.04
3	0	0.00	10.77	28.54	35.81	46.77
3	5	0.00	10.56	13.07	7.18	22.98
3	10	0.00	0.00	0.00	5.82	31.57
3	15	0.00	0.00	0.00	0.00	12.36

development of juice in persimmon fruits because of the semi permeable layer around the treated fruits surface. The semi permeable layer modified the internal atmosphere by limiting availability of oxygen for respiration, accumulation of high level of carbon dioxide inside the coating and ethylene entrance to the fruit [Dong et al. 2004]. The combination of low oxygen and higher carbon dioxide can have a synergistic effect in suppressing ethylene biosynthesis, which reduces the development in juice content of the coated fruits.

Persimmon fruits dipped for more time in higher concentrations of chitosan solution attained high volume, this could be due to the fact that semi permeable coating of chitosan over fruit surface may act as an obstruction for loss of excessive moisture from fruits through transpiration and maintain higher volume during storage. During the postharvest period increase in rate of respiration and production of ethylene leads to ripening and senescence of the fruits, which is linked with variation in various qualitative parameters such as development of aroma and colour, reduction in titratable acidity, increase in sugar content and decrease in firmness; in some of the fruits like persimmon these changes may enhanced juice content [Elabd and Gomaa 2017].

Generally firmness of the fruit decreases during storage, which might be due to conversion of protopectin to more soluble pectin and pectic acid, water evaporation and nutrients consumption [Qi et al. 2011]. The decreasing trend in firmness of uncoated (control) fruits might be due to rapid evaporation, higher rate of enzymatic activities, respiration and disease occurrence, which is retained effectively in fruits with higher concentrations of chitosan coatings. Minimum firmness of control fruit might also be due to absorption of more water by surface of the fruits, which causes softening of the fruits and thus results in less firmness. Application of chitosan edible coating could restrain the evaporation and thus more water is reserved and the cells of fruit retain higher swelling pressure and showing higher firmness. The results are supported by the findings of [Ali et al. 2011], who found that papaya fruits coated with chitosan showed higher firmness than uncoated fruits.

The total soluble solid (TSS) content is reflected as a vital aspect for quality of the fruit because it contains 75% of fruit sugars. Moalemiyan et al. [2012] reported that starch content of the fruit during storage degrades rapidly to soluble sugars by the action of various enzymes such as starch-phosphorylase, 1,6-glucosidase and amylases. TSS mainly rises due to increasing level of free sugars within the fruit and in combination with acidity, it provides taste and flavour to the fruit [Malundo et al. 2001]. During post-harvest stages TSS content of the fruits rises gradually, thus the increase in TSS is caused by respiration through which the starch converted into soluble sugar (sucrose, glucose and fructose). Application of chitosan coating decreases the process of respiration because it forms a thick layer over fruit surface, thus minimizes the oxidative breakdown of starch into soluble sugars and showed lower TSS value. The current results are supported by findings of Ghasemnezhad et al. [2011], who reported that strawberry fruits coated with chitosan reduced the development of soluble solid because it acts as a barrier for exchange of oxygen and carbon dioxide thus reducing the process of respiration and metabolic activities i.e. transformation of starches into sugar, water and carbon dioxide. These results are also similar to that of Ahmed et al. [2009], who concluded that the coating of aloe vera gel reduced the increase in TSS in nectarines because it reduces the rate of respiration and catabolic activities.

Organic acids present in the fruits are responsible for acidity of the fruits which releases hydrogen ions due to which rise in acidity takes place, indicating the ripening and senescence stages of the fruit [Scalon et al. 2012]. Malic and citric acid are the main organic acids present in fleshy fruits like persimmon. In the current study, lower acidity in uncoated fruits during storage might be due to disintegration of organic acids into sugars through the process of respiration [Díaz-Mula et al. 2012]. Han et al. [2004] used chitosan as a coating material on raspberry and strawberry fruit and reported that edible coating of chitosan decreased the fruit acidity and effectively delayed ripening and senescence. Chitosan coating form an obstruction for gaseous exchange and raise the concentration of internal CO_2 which creates modified internal atmospheric conditions thus suppresses the process of respiration and catabolizing the organic acids contributing to acidity, which eventually results in slower reduction of titratable acidity and ripening of fruits. These results are in accordance with the findings of Ali et al. [2011],

who found that when papaya fruits were treated with chitosan, a slight decrease in titratable acidity was observed during storage as compared to the uncoated fruits.

The TSS/acid ratio is one of the important characteristics for taste and quality of the fruit. In immature stage, TSS to acid ratio of fruit is low but in mature fruits this ratio is high. Fruits with sour nature have lower TSS/acid ratio but high in sweeter ones. The reason for high sugar to acid ratio is the conversion of starch into sugars which rises TSS, whereas reduction in organic acids take place during fruit ripening which results in high sugar acid ratio. In the current experiment there was rapid increase in TSS/acid ratio in fruits that were not treated with chitosan, which led the fruit to senesce with short post-harvest life, while chitosan coated fruits showed a slight increase in TSS/acid ratio. Fruits with chitosan coating might perform a part in delaying ripening and senescence. Ghasemnezhad et al. [2011] reported that, with the advancement of low temperature storage condition the TSS/acid ratio of the fruit increases and led to drop in flavour. According to Petriccione et al. [2015], due to the slow senescence process of chitosan coated loquat fruit in cold storage condition exhibited a slight increase in TSS/acid ratio in comparison to non-coated fruits.

Fruit juice pH is another important flavour qualitative parameter in addition to soluble solid. The normal pH of persimmon fruit is 5.33, which increases slowly during ripening and reaches to higher value up to 6.12 [Ramin and Tabatabaie 2003]. The pH of fruits primarily depends on the concentration of organic acids. As the storage period of fruit increases, organic acids are consumed as respiratory metabolite that results in higher pH and lower acidity [Rivera-López et al. 2005]. The application of chitosan coating creates a semi permeable layer on fruit surface, which limits the availability of oxygen thus minimizing respiration rate due to which organic acids are prevented from being consumed as a respiratory metabolite that result in lower pH values. The results of this experiment are in close agreement with Maftoonazad and Ramaswamy [2008], who described that higher pH was recorded in uncoated avocado fruits as compared to coated fruits.

The most vital component in fresh fruit is ascorbic acid, which has high antioxidant properties. Ascorbic acid content of the fruit decreases during the period of storages, the introduction of oxygen, heat, light and high pH are the various factors, which are responsible for its decline [Sritananan et al. 2005]. Fruits treated with different concentrations of chitosan edible coatings cover the pores present on fruit skin thus restrain the in and out of oxygen which hinder the respiration process and therefore slowed down the process of ascorbic acid oxidation [Wahab and Rashid 2012]. High levels of ascorbic acid in fruits dipped in chitosan higher concentration (2% and 3%) for maximum duration (10 and 15 min) might be due to the formation of chitosan thick coating which limits the availability of oxygen to the fruits cells so the process of respiration is controlled and the breakdown of ascorbic acid is minimized which results in high ascorbic acid contents, while the control fruits were exposed to external oxygen where the rate of respiration was high and more break down of ascorbic acid takes place resulted in lower ascorbic acid content of the fruits. Results of the present research are also in accordance with the findings of Dang et al. [2010], who found that *Prunus avium* fruit coated with higher levels of chitosan concentration had shown higher level of ascorbic acid which might be due to the low oxygen availability that hindered the enzymatic activities responsible for ascorbic acid oxidation in the fruit.

As the results showed that fruit decay in chitosan coating formulation was lower than uncoated fruits, similar results were reported in other studies and they found that chitosan coating efficiently control post-harvest decay, reduces the onset and development of infection. The chances for microorganisms to contact the fruit surface has been reduced after application of chitosan edible coating, thus ensuring fruits free from microbial invasion. Reduced rate of respiration, cell membrane integrity, maintenance of higher activities of protective enzymes are some of the factors that support the ability of fruit to restrict phytopathogen activities. These results co-relates with the outcomes of Bautista-Baños et al. [2006], who observed a decline in post-harvest decay incidence of apples and cucumber coated with chitosan.

Water loss from surface of fresh fruits caused by the process of transpiration mainly results in weight loss of the fruit [Zhu et al. 2008]. Application of chitosan edible coating creates a semi-permeable transparent membrane around the fruit surface, which can act as

a protecting obstacle for minimizing the rates of transpiration and respiration processes occurring through skin of the fruit. Coating the persimmon fruit with chitosan was noticeably effective in conferring a physical barrier to water loss and is therefore a decrease weight loss in fruits was noticed. Results of the current experiment are in line with previous finding of researchers, who observed that application of chitosan edible coating were effective in minimizing weight loss of Mango fruits [Zhu et al. 2008] and peeled litchi fruit [Dong et al. 2004].

CONCLUSIONS

Persimmon fruits dipped in 3% chitosan concentration resulted in minimum juice content, TSS, pH, TSS/acid ratio, decay incidence and weight loss, while having maximum fruit volume, firmness, titratable acidity and ascorbic acid content. Among various dipping time persimmon fruits dipped for 15 min showed minimum juice content, TSS, pH and TSS/acid ratio, while having maximum fruit volume, firmness, titratable acidity and ascorbic acid content. It is recommended that persimmon fruit should be treated with 3% chitosan solution for 15 min dipping time after harvest to maintain the quality attributes in the storage at ambient conditions (25–29°C and 55–70% RH).

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